action of food stuffs, finds that glycocoll has a specific dynamic action of 100, alanin of 50.

Many of these results of nutrition studies can not be used with confidence in problems of human nutrition until more is known about the differences in the amino acid content of the flesh of different species. The pig can use 23 per cent. of wheat proteins for growth, but we can not yet be sure that this is true of the child; and so of many of the other very interesting and valuable contributions cited. They suggest wonderful possibilities—future possibilities—for the dietitian: a child who is undersized and frail can sometime be fed just the right combination of milk, eggs and cereals to furnish the amino acids he needs in the right proportion with no large excess of any one to overtax the excretory system or to overstimulate metabolism; a worn-out neurasthenic can be given just the right amino acids to replace worn-out tissue and enough glycocoll to stimulate metabolism—in gelatin perhaps. We have some slight clinical evidence that this last works out.

THE MINERAL NUTRIENTS IN PRACTICAL HUMAN DIETETICS

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IN consenting to present this paper I did so with the feeling that perhaps I have as good right as any one else to confess for all of us that we know very little about the subject. The suggestions I have to make then are offered in entire humility and with satisfaction only that we are on the road to more complete understanding.

My task is to point out the bearings of results of experiments in the field of mineral metabolism upon our irrational, uncontrolled and largely uncontrollable human dietetic affairs. Only in the case of infants, invalids, lunatics and convicts does it seem practicable to regulate the diet of human beings with the same rationality and particularity with which the successful live-stock farmer habitually feeds his animals. In spite of the difficulties of the task, however, and the indifference of most of us to the economic and rational aspects of our own eating, there are those dependent upon us who should have the benefit of our wisest counsel, even though we put ourselves in the position of saying, "you are to do not as I do but as I say."

In order to bring clearly to mind the basic principles of nutrition involved in this consideration I must enumerate the functions of the mineral elements in animal metabolism:

As bearers of electricity the mineral elements dominate the whole course of metabolism.

They conduct nerve stimuli, and play a leading rôle in the general process of cell stimulation.

They govern the contraction of the muscles, including those of the heart.

They compose the central agency for the maintenance of neutrality in the blood.

They enter into the composition of every living cell.

They compose supporting structures.

They assist in the coordination of the digestive processes.

They activate enzymes, and through their control of the chemical reaction of the blood and tissues they govern enzyme action.

They unite with injurious products of metabolism, and render them harmless or useful.

As catalyzers they alter the speed of reactions, and the rate of metabolism generally, as measured by oxygen consumption.

Through their effects on osmotic pressure they govern the movement of liquids, and maintain the proper liquid contents of the tissues.

Through their effects on surface tension they participate in the mechanism of cell movement.

Through their control of the imbibition of water by the colloids they govern absorption and secretion.

Through their control of the affinity of the blood for gases they govern respiration.

Finally, they control the state of solution, precipitation, mechanical aggregation, chemical association and ionization of the colloids which compose living tissue.

These then are some of the functions of the mineral elements. Considering their nature and importance, it is at once obvious that life could not endure if its complex mineral requirements were not automatically and constantly maintained in almost perfect adjustment. What then are the facts which warrant the practical consideration of this subject? They are that in pathological states these functions are somewhat deranged, and that life as we live it is in many respects highly abnormal, in the sense of differing from that to which human metabolism is attuned; and with our ever-increasing social differentiation life puts increasing stress upon the integrity of the body and its normal processes. In relation to food materials there are also important facts bearing on this matter of the mineral nutrients, for while highly developed processes of food manufacture and efficient world-wide transportation give us the greatest opportunities for correct dietetics that there has ever been, these same agencies open the way to greater unwisdom and abuse in dietetics than have been possible in our more primitive days. The net result is an obligation on our part to prepare a defense of knowledge against the misfortunes of prosperity.

It is my belief that anything like exact quantitative control of human mineral metabolism, as a practical measure, is as impossible as it is unnecessary; impossible first, because any kind of control of human dietetics is very difficult; second, because our knowledge of the optimum mineral requirements of human beings is especially slight and fragmentary; third, because the interactions of the mineral elements among themselves affect mineral metabolism in such prominent ways that fixed and definite statements of mineral requirements are quite apt to be misleading. And exact control in these matters is unnecessary because of the existence of safety provisions, for bridging over temporary deficiencies, of a perfection in harmony with the surpassing importance of mineral metabolism.

It is my belief, therefore, that in our present state of knowledge close statements of the mineral requirements of human beings involve a large element of "ceremonious delusion" (borrowing the expression from Thudichum), and that practical advice regarding the mineral metabolism of healthy human beings may most properly be general in character, and in the nature of recommendations of *types* of food products which should predominate in the diet under the various conditions of life, growth and activity.

We shall discuss certain of the mineral nutrients in detail, citing facts as to their occurrence in foods and metabolism in the body.

The one mineral salt which we use as such—sodium chloride—occupies a unique position among the mineral nutrients. Within wide limits it seems to make little difference how much sodium chloride we consume, and the kidneys excrete this salt without marked energy expenditure. Under certain conditions excessive intake of this salt causes slight increase in nitrogenous outgo, but such abnormal consumption would result in indigestion before the increased protein katabolism would become important in extent.

A special method and capacity of the kidneys for the elimination of sodium chloride is shown by observations of Schloss[1] and of Borchardt.[2] It appears that this salt alone fails to cause a loss of water from the body corresponding to the amount of salt eliminated.

Bunge relates our unusual appetite for salt to the potassium content of the diet, and the antagonistic relation between sodium and potassium which exists in metabolism. It takes such a quantity of potassium salt to cause an appreciable increase in the elimination of sodium, however, that I prefer to explain our peculiar relations to sodium chloride as due to the marine origin of vertebrates and the consequent adaptation of these forms to life in a somewhat concentrated solution of this salt.

Other physiological antagonisms which are often mentioned are

[1] Schloss, *Biochem. Z.*, 22, 283–89.

[2] Borchardt, *Deut. med. Wochenschr.*, 38, 1723–27.

those between calcium and magnesium and between calcium and sodium; other less important ones have been shown to exist between chlorine and iodine, and between chlorine and bromine.

The retention of the minerals is also prominently affected by their relative abundance in comparison with the requirement, that is, by the so-called "law of minimum," the least abundant constituent, as compared with the demand, serving largely to determine the usefulness of others with which it is associated in metabolism. The various salts of the diet also affect the solubility of others of this same group of nutrients in important ways.

The net result of these interrelationships among the mineral nutrients is likely to be manifest as a prominent lack of correspondence between the retention and the intake of these substances. The man to whom quantitative relations in mineral metabolism appear to be simple and direct is not embarrassed by an acquaintance with much of the evidence.

Calcium, phosphorus and iron are more likely than other mineral nutrients to be lacking in human dietaries. On this account especial interest attaches to their occurrence in food. Calcium is especially abundant in milk, and is also contained in considerable quantities in eggs, vegetables and fruits. Phosphorus is abundant in milk, eggs, nuts, peas, beans and such cereal products as contain the outer seed coats. Iron is found in largest quantities in beef, eggs, beans, peas, green vegetables (especially spinach) and in the outer seed coats of the cereals. The foods which are poorest in minerals are polished rice, pearl hominy, white flour, bolted cornmeal and other cereal foods which lack the outer seed coats. These foods, because of their highly digestible character and lack of salts, are apt to be constipating. Magnesium is abundant in the cereals and is not apt to be deficient in normal rations. The magnesium salts of the outer seed coats of cereals contribute a laxative character to foods containing them. Enough sulphur is contained in the proteins of any ration which supplies the nitrogen requirement. Potassium is found in considerable quantities in most normal foods and is also present in sufficient amount in almost all diets.

Manganese, boron, silicon and iodine are among the less abundant minerals in the body, the presence of which in the necessary quantities in the diet we take for granted. We are just now finishing up in my laboratory iodine estimations on about 950 samples of food products in a study which will show in what foods iodine is found, and which may perhaps show a relationship of the iodine of foods to the prevalence of goiter.

Considering the proportion of minerals to other nutrients needed during the several stages of life, there is, from birth to maturity, in general a decreasing requirement, but with periods of increased demand due

to unusual functional activity, especially during puberty, pregnancy and milk secretion. The usual mineral requirements of mature human beings are comparatively slight, and are probably satisfied by all normal diets (provided we specify with some particularity as to what constitutes a normal diet). It is, therefore, during rapid growth and during the reproductive life of women that the mineral nutrients are especially in demand, and it is at these times that lack of mineral nutriment and irrational hygiene cause or aggravate a number of well-known pathological conditions which are characteristic of these states of being. We shall mention in detail the mineral requirements at some of these times of greater need.

The normal food of the human infant naturally furnishes its full mineral requirement. This subject becomes of interest in this connection, therefore, in cases of artificial feeding and in certain metabolic derangements. For an artificial food we naturally turn first to cow's milk, which because of high fat and casein contents must be liberally diluted. If water is used, the necessary dilution reduces the minerals, the albumin, the lecithin and the so-called accessory nutrients to an undesirable extent. The best diluent is whey, which any one can prepare with the aid of a thermometer and a commercial rennet preparation in a few minutes. (The whey must be heated to 68° C. or 154° Fahrenheit to kill the enzyme, before it is mixed with milk.) With combinations of whey, skim milk, cream and milk sugar you can play any dietetic tune you please on the infant organism, and with these foods the intelligent parent can rear any infant which can live at all. The especial usefulness of whey is due to its abundant mineral content in natural physiological solution. It serves as a stabilizer—a corrective. You can do no harm with whey unless you use the evaporated preparation, whey powder. It is possible by an abuse of this food to cause edema (in weak infants) through excessive ingestion of minerals, though this would never occur in its proper use.

The commonest metabolic disturbance in infants is gastrointestinal indigestion. Its commonest cause is a weak digestive apparatus and too much fat in the food. Alkali soaps, formed in the intestine, instead of being digested and absorbed are passed off in the feces. Alkalis are lost to the organism; mineral acids are left to predominate; infantile acidosis ensues. What shall we do? Reduce the fat in the food and add sodium citrate to furnish an oxidizable alkali salt.

Because of its low oxidative capacity the infant organism is especially subject to acid intoxication from relatively slight causes, the acid excess being due to the normal acid products of metabolism and to imperfectly oxidized organic compounds, especially betaoxybutyric acid. We have mentioned the weak digestive apparatus and deficient capacity to handle fat. Inanition also causes acidosis in infants. Fever is a

very common cause. In all these cases whey is especially valuable. Many a child has been taken through long sieges of fever on whey. Children do not lose weight rapidly on whey alone. Egg white and fruit juice, especially that of the orange, may be used with whey to advantage; they furnish some nutriment and appreciable amounts of alkali.

The infant is born with a store of iron within its body. During the nursing period this store is gradually depleted, since the milk contains little iron. At weaning time the infant stands in need of iron. This is usually supplied in egg yolk, beef press juice, scraped beef, prunes, whole wheat foods and oatmeal, and some physicians of unquestioned standing recommend spinach. I happen never to have seen spinach used, however, for an infant. Egg yolk is of especial value as a source of iron, calcium, phosphorus and lecithin. But it is an exceedingly rich food. It must be fed with great care on two accounts, first, to avoid making the baby sick, because while it is usually well taken it acts like poison to some infants, and second, because the value of egg is so great that it is especially unfortunate if you upset the infant by an overallowance, since it may be a long time before it will regain its tolerance for this food.

In connection with the mineral metabolism of infants mention must also be made of rachitis. The cause of this disease is unknown. It is not due *primarily* to lack of minerals in the diet and does not respond readily to simple increase of minerals in the food, though calcium salts administered with phosphorized cod-liver oil are usually beneficial.

The existence in infants and older children of simple malnutrition of the bones, a common malady in young farm animals, is not well established; and the prevalent imperfections of children's teeth are not certainly related to deficiencies in the diet, but seem rather to be caused by lack of exercise (due to the fine milling of our cereals and the chewing of our meat with a sausage mill), the increasing use of sugar (a readily fermentable, acid-producing food) and increasing use of fruits, the organic acids of which soften the tooth enamel.

In considering the mineral requirements of human beings we may bear in mind the facts that more than three fourths of the ash of the body is in the skeleton, which includes about 88 per cent. of the phosphorus and more than 99 per cent. of the calcium of the entire body. Thus in discussing mineral requirements of the organism as a whole we have to do very largely indeed with the skeleton, but we must not overemphasize these facts, for the quantities involved are no gauge of functional importance, as is illustrated by the fact that iodine, which is found in the body in infinitesimal amounts, is just as essential as the pounds of calcium.

Beyond the period of infancy the mineral nutrient which is most commonly lacking in the diet is calcium, though phosphorus also may be

deficient, and the iron content of the diet is sometimes inadequate, as evidenced by the existence of anemia in children.

For purposes of growth our best single sources of mineral nutriment are milk and eggs. Of these, milk lacks only iron, and eggs only calcium. The incubating bird supplements the moderate calcium content of the egg by absorbing an appreciable amount of lime from the shell.

During the reproductive life of women liberal use should be made of the iron-containing foods, such as beef, eggs, fruits and green vegetables, especially spinach, green beans and cabbage. Lactation makes a heavier demand upon the mother for mineral nutriment than any other incident in her life, and the most efficient method of providing the mineral requirement is, naturally, through the use of milk, or foods made from milk.

In old age there seems to be an absorption and loss from the body of much bone substance coincident with the general atrophy of the tissues. This is most apparent in the receding of the processes of the maxillæ and the absorption of the spongy structure of the interior of the long bones. This appears to be a physiologic process, and we have no evidence that it is affected one way or the other by the minerals of the diet, though it is conceivable that there might be some such influence.

Generally speaking, a high ash content of the food is desirable, since the organism is much better able to handle an excess of ash constituents than to meet a deficiency. It is good practise, therefore, to utilize the water in which foods are cooked, in so far as this can be done without detracting from the acceptability of the food, since the cooking-water dissolves out much mineral matter. An abundance of mineral salts in the diet is also desirable, aside from nutritive considerations, because they contribute a laxative character to the food. Foods which are deficient in minerals are apt to be constipating.

A general character of the mineral nutrients of foods is the predominance of acid or basic elements. If the nutrients are present in the proportions in which they are needed the bases will predominate, and it is probably best that the bases should exceed the acid elements in the diet. It is true, however, that the organism has the capacity to neutralize a considerable excess of acids. Meats, eggs and cereals have acid ash; vegetables, milk and most fruits have alkaline ash. The latter group should be liberally represented in the diet.

The diets which are most likely to supply enough of each of the minerals are those characterized by liberality and diversity. Extreme simplicity of diet is not advantageous. The usual diets of prosperous Americans do not lack mineral nutrients. But we are not all prosperous, and some of us choose unusual dietetic combinations. The central features of improperly chosen diets are usually an undue dependence upon meats and foods made from finely milled cereals or other cereal

foods lacking the outer seed coats, and too little use of milk and vegetables.

Those circumstances most likely to lead us into error in this matter are ignorance, poverty, parsimony, dietetic fads, peculiarities of appetite and disordered digestive functions.

Now in conclusion, it is certainly true that we muddle along fairly well without much attention to this subject, but one never knows when he may need additional insurance in the way of understanding. Through my slight knowledge of this subject I was able to save my own son, and that of course seems to me to have been worth while. Then too, when there be no lives in danger, there is a certain satisfaction which we all take in efforts to direct our affairs with intelligence even though "the worst laid plans of mice and men gang oft aright."

THE CHEMICAL NATURE AND PHYSIOLOGICAL SIGNIFICANCE OF SO-CALLED VITAMINES

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IT has been known for some time that scurvy is a disease which occurs in man and certain higher animals when the diet does not contain fresh vegetable or animal foods. Once the disease has made its appearance it can be cured in most cases in a remarkably short time by the introduction into the diet of the patients of a sufficient amount of fresh vegetables, fresh milk and especially fresh lemon juice. Hence it is obvious that these last-mentioned foods contain in their fresh state substances which are essential for the prevention of scurvy. As a diet which otherwise is fully adequate from the point of view of its content in proteins, carbohydrates, fats and calories may lead to scurvy, the logical conclusion is that there exist in fresh vegetables and certain animal foods substances of an unknown chemical composition which are essential accessory foods.

The deficiency of the diet in similar substances may give rise to a disease of the peripheral nervous system, known as beri-beri, which is especially prevalent in eastern countries, as Japan and the Philippines. People living on a diet which consists almost entirely of highly milled rice or wheat are very apt to develop beri-beri after having lived on this diet for a period of ninety days. On the other hand, beri-beri does not develop in persons living on whole rice or wheat flour. In other words the outer portions of these cereals, namely the aleuron layer, contain the substances which have to be added to the diet in order to prevent this disease. As in the case of scurvy, a considerable number of observations have established the fact that beri-beri is not due to a deficiency of the